WATER PRICE IMPACT ON RESIDENTIAL WATER DEMAND IN THE CITY OF ZARAGOZA. A DYNAMIC PANEL DATA APPROACH

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Abstract:

As Winpenny (1994) argues, "the aim of managing demand is to ensure that a given supply of water is distributed to accord more closely with its "optimal" use pattern. Managing demand entails taking into account the value of water in relation to its cost of provision, and introducing measures that require consumers to relate their usage more closely to those costs. It entails treating water more like a commodity, as opposes to an automatic public service.

In this context, we carry out a data panel analysis with the aim of establishing the determinants of the residential water demand in Zaragoza. Water purchases of family residences are regressed on price, income, household size and a dummy variable for hot water disposability by dynamic panel data approaches based on a sample of 3000 observations from Zaragoza city referred to 1996-1998. From the estimation of the elasticity-price of the residential water demand we want to know how a policy of responsive pricing can lead to a more efficient household water consumption in Zaragoza city.

1. Introduction

In this paper we present an empirical study aimed at determining the extent to which pricing measures could lead to the more efficient use of water on the part of families connected to the public water supply of the city of Zaragoza in North-eastern Spain. Thus, the central objective of the paper is to obtain an estimation of the price elasticity of the demand for water for domestic uses that will allow us to evaluate the role of prices as a management instrument within such a supply system. The paper is organised as follows. In Section 2 we offer a general description of the study area. The main characteristics of the sample are described in Section 3. Section 4 is dedicated to the variables included in the proposed demand model, whilst the fundamentals of the technique used to estimate it are dealt with in Section 5. Section 6 presents the results of the price elasticity and Section 7 closes the paper with some final considerations.

2. General framework

As already mentioned, the territorial ambit within which this empirical study has been carried out is the municipal district of Zaragoza. This city, which lies in the central area of the Ebro Basin, has a Continental-Mediterranean climate; that is to say, it is characterised by extremely high temperatures in the summer and intense cold in the winter. Additionally, there is a certain tendency towards periods of drought, given that the rainfall, apart from being limited -an average of approximately 334 mm per year- has a marked inter-monthly and inter-yearly irregularity, with long periods during which no precipitation whatsoever is recorded.

From a demographic point of view, Zaragoza has enjoyed sustained growth since the beginning of the twentieth century, passing from 100,291 recorded inhabitants in 1900 to a population of 601,674 according to the Municipal Census of 1996.

The city is supplied with water by the River Ebro. This supply is either indirect, through the *Canal Imperial de Aragón*, or direct from the river itself when this canal is subject to civil engineering work or cleaning. Although, in general terms, the city has a relative abundance of water, its dependence on a single source of supply places it in a somewhat delicate position in the medium term. The continuing growth in the population has led to the demand for water by the city as a whole reaching very high levels, which are drawing increasingly close to the physical limits of this source of supply. Apart from this quantitative problem, which appears on a limited time horizon, another factor that conditions the availability of the resource in Zaragoza to a considerable extent is the low quality of the water in the River Ebro at the various withdrawal points. This is particular the case during periods when the river is running at low levels and there is a significant increase in the pollution load, to the detriment of water quality.

Finally, we should note that within this municipal district the distribution of the residential water supply is in the hands of the City Council under a direct management formula, in such a way that we are dealing with a service provided under monopoly conditions by the public sector.

3. Characteristics of the sample

The analysis has been carried out using panel data from a random sample of 3,000 users of the domestic water supply in Zaragoza. This sample contains the following information:

1. The consumption registered on the water meters of the households (almost invariably flats) contained in the sample during the period 1st November 1995 to 31st October 1998, a total of 12 readings.
2. The unit price paid for the water consumed, calculated on the basis of the official tariffs provided for in the corresponding Municipal Regulations.
3. The fiscal value of the different flats in the sample.
4. The number of individuals who live in each of the households according to the Municipal Census.
5. The availability of a common supply of hot water to the building in which the flats are located.

The Municipal Computer Service of the Zaragoza City Council has provided the information on consumption, the fiscal value and the number of residents per household. The data on the availability of a common supply of hot water in the different buildings has been obtained through a telephone survey carried out for that purpose. Finally, and as mentioned earlier, the price of the water has been obtained by applying the tariffs in force at each moment in time to the consumption data.

Having processed the original information, we have proceeded to eliminate those elements of the sample in which one of the following circumstances is present:

1. Anomalies in the water meter readings, essentially negative quarterly consumption, indicating a possible defect in the meter.
2. The substitution of one water meter for another during the period under study.

3. A consistently unchanged reading or readings that hardly altered from one period to the next, thereby demonstrating that the flat was habitually vacant.
4. Anomalies in one of the other variables, that is to say, the fiscal value, the number of residents and the availability of a common supply of hot water.

The result of this process was a significant reduction in the size of the initial sample, to one that was now made-up of 1,596 individuals. Furthermore, the existence of a duplicated meter reading meant that these also had to be eliminated, reducing the number of periods to 11. Once the calculation of consumption had been made as the difference between the readings of one period and those of the previous period, this number was finally reduced to 10 observations covering the period 1996-1998. In this way, the panel changed from one that initially comprised of 36,000 readings -3,000 individuals by 12 periods- to one that finally contained 15,960 readings -1,596 individuals by 10 periods-.

4. The proposed model

In this Section we will briefly describe the most relevant aspects of the variables that are included in the water demand function to be estimated.

1. Water consumption

The main drawback when choosing a concrete specification for this variable is that the periods that separated the water meter readings varied from 63 to 114 days.

For this reason, we have chosen to use the daily consumption of each of the meter reading periods considered in the model as the endogenous variable. In this way we have lost an element of realism, given that it is difficult for individuals to know precisely the amount of water they consume each day. However, we have gained in the operative aspect, as the chosen option allows us to work with a data sample that refers to a uniform time period.

2. Income

It has been impossible for us to obtain specific information on the disposable income of each of the individuals making-up the sample. Thus, and following the approach adopted in different empirical works, Dandy, Nguyen and Davies (1995) or Nieswiadomy and Molina (1989), amongst others, we have used the fiscal value of the flat recorded in the Urban Property Register as the indicator of this variable. In this way, we have individual data that is much more reliable than that obtained on the basis of aggregate data on disposable income reflected in the official statistics.

3. Socio-economic variables

We have considered two variables in the demand model: the number of individuals who reside in the household and a dummy that represents the availability of a common supply of hot water in the building in which the flat is located. This dummy reflects the existence of individual water consumption that is registered on a common water meter, one that is different from the private meter, with this consumption not being paid for directly to the City Council by the final users.

4. Price

The unit price paid for the water consumed in each one of the periods considered has been calculated on the basis of the official tariffs contained in the Municipal Regulations of the Zaragoza City Council.

These tariffs include a fixed part and a volume charge. The fixed part is a public price that must be paid in order to have the possibility of being connected to the water supply. The volume charge is applied according to a progressive tariff made-up of 140 blocks of consumption. Thus, we have a contrast to what takes place habitually in the block tariff structures, where the units lying within the different consumption blocks have different prices for the user. In the case of the Zaragoza city supply, the established tariff has the peculiarity that all the units recorded on the meter are paid for at the same price, with this being given by the block corresponding to the last unit consumed.

Under these conditions, it is very complicated, both technically and economically, for the individual users to be able to obtain the necessary information so as to precisely determine the marginal price associated to their consumption at each moment in time. As a result, and in line with that proposed in Charney and Woodward (1984) and Shin (1985), we have considered that the consumers, when taking their consumption decisions, will tend to use the price information that is least costly for them. Such information will normally take the form provided by the water bill that they receive periodically in their homes.[1] In this way, the specification adopted for the price variable is the total amount paid by individuals for the water consumed divided by the number of days of the meter reading period, with our objective being to obtain a homogenous measurement. Given that the individuals receive their water bill six months after the meter reading (that is to say, two readings behind), the choice of this characterisation supposes in practice that we are using the bill for the water consumed by each individual lagged two periods (p_{it-2}) and divided by the number of days between each meter reading. Here, our objective is to have a price variable that is homogenous for all users.

5. Estimation of the model

The economic literature does not contain any evidence that fully justifies the most adequate functional form for residential water demand. In our case, we have chosen to estimate a demand equation that has the following specifications:

$$q_{it} = e^{b_0 + dp_{it-2} + x'_{it} b} \; e^{u_{it}} \qquad (1)$$

in linear terms:

$$\ln q_{it} = b_0 + dp_{it-2} + x'_{it} b + u_{it} \qquad (2)$$

where b_0 is the independent term, d is the parameter of the price p_{it-2} and b is the vector of parameters that accompanies the variables vector x_{it}, which encompasses income, the number of residents in the household and the availability of a common supply of hot running water. For its part, the error term u_{it} can be broken down in the following form

$$u_{it} = m_i + v_{it}$$

with m_i ~IID(0, s^2_m) and v_{it} ~IID(0, s^2_v) following Baltagi (1995).

As can be appreciated in model (2), p_{it-2} is included in the set of explanatory variables. In this context, and given the tariff structure currently in force in Zaragoza, where the price is linked to the amount consumed, we can observe that:

$$p_{it-2} = f\left(q_{it-2}\right) \qquad (3)$$

in such a way that model (2) is dynamic, although the dynamism appears indirectly.[2]

This means that the variable p_{it-2} in (2) is correlated with the error term u_{it} by way of m_i. Within this framework, the OLS estimation of the parameters is biased and inconsistent, even if v_{it} is not-autocorrelated, as indicated in Baltagi (1995), Arellano and Bond (1991) and Arellano (1989).

Following these authors, the adequate transformation to correctly estimate model (2) is the first difference (FD) transformation, that is to say:

$$\ln q_{it} - \ln q_{it-1} = d \; (p_{it-2} - p_{it-3}) + (x_{it} - x_{it-1}) \; b + (v_{it} - v_{it-1}) \qquad (4)$$

in such a way that the individual effect of the error term that caused the correlation with the price variable is eliminated. Together with this term, the exogenous explanatory variables (x) also disappear in (4), given that we are dealing with socio-economic variables that take the same value for the different time periods being considered. As a result, it is possible to write (4) as:

$$\Delta \ln q_{it} = d\ \Delta p_{it-2} + \Delta v_{it} \qquad (5)$$

in such a way that we can obtain the estimation of d, but not that of the other parameters.

When the endogenous explanatory variable has only one lag, this gives rise to a correlation between this, in differences, and the error term, which requires that we use instrumental variables. The optimal estimation of these models is obtained by the so-called Generalised Moments Method (GMM).[3] However, in expression (5) there is no correlation between Δp_{it-2} and Δv_{it}, given that these do not coincide in any lag, although there is an autocorrelation problem in the error term.[4]

If we try to apply this procedure to the proposed model, a first step should be to estimate (5) by GLS, taking, of order NT x NT, as the matrix of variances and covariances of the error term (Δv_{it}) $s_v^2\,\Omega = s_v^2\, I_N \otimes \mathrm{G}$, where $\otimes$ indicates the Kroneker product and I_N is the identity matrix order N (number of individuals). Thus, we obtain a first estimation of d ($\hat{d}_1$), that will be used in order to calculate the residuals $\Delta \hat{v}_{it}$:

$$\hat{d}_1 = \left(\Delta P'_{-2}\Omega^{-1}\Delta P_{-2}\right)^{-1}\ \left(\Delta P'_{-2}\Omega^{-1}\Delta\, ln\, q\right) \qquad (6)$$

where

$$\Delta P'_{-2} = \left(p_{i2} - p_{i1} \quad p_{i3} - p_{i2} \quad \cdots \quad p_{iT} - p_{iT-1}\right)'$$

$$\Delta\, ln\, q' = \left(ln\, q_{i4} - ln\, q_{i3} \quad ln\, q_{i5} - ln\, q_{i4} \quad \ldots \quad ln\, q_{iT} - ln\, q_{iT-1}\right)'$$

The second stage consists in estimating model (5) once again by way of GLS, where, instead of Ω, we use the matrix

$$\hat{V}_N = \sum_{i=1}^{N} \Delta \hat{v}_i \Delta \hat{v}'_i \qquad (7)$$

On this basis, we obtain the following estimator for the price parameter:

$$\hat{d} = \left(\Delta P'_{-2}\hat{V}_N^{-1}\Delta P_{-2}\right)^{-1}\ \left(\Delta P'_{-2}\hat{V}_N^{-1}\Delta\, ln\, q\right) \qquad (8)$$

in such a way that the complete process up to the obtaining of $\hat{d}$ can be called “a two-steps GLS”.

The above estimation procedure follows the same lines as established by Arellano and Bond (1991) for the estimation of a dynamic panel. As an alternative, we have the habitual econometric practice when a model presents unknown autocorrelation problems. This consists in estimating by way of OLS in a first stage, using the residuals of this estimation to obtain an estimation of the variances and covariances matrix, and applying the GLS procedure in a second stage. In analytical terms, the estimation given in (6) is substituted by:

$$\hat{d}_1 = \left(\Delta P'_{-2} \Delta P_{-2}\right)^{-1} \left(\Delta P'_{-2} \Delta \ln q\right) \qquad (9)$$

and in the second stage we proceed in the same manner as in (7) and (8).

In this study we present the results obtained by applying both estimation procedures, and we can note the similarity between them.

Although the central objective is to determine the sign and magnitude of the price coefficient, model (2) presented other explanatory variables, of a socio-economic character, that did not appear in differences model given in (5), although they are in it in an implicit form. To approximate the value of the parameters that accompany these variables, we can use a method similar to the so-called "two-step Durbin procedure", a technique that has been widely employed in linear models where there is unknown autocorrelation. Specifically, with $\hat{d}$ being known, from equation (2) we obtain:

$$q_{it} - \hat{d}\, p_{it-2} = x'_{it} b + e_{it} \qquad (10)$$

an expression that corresponds to a static model with panel data, whose estimation will allow us to obtain an approximation of b. Bearing in mind that the presence of random effects was considered in model (2), a logical form to estimate (10) is to take these into account, in such a way that the estimation technique proposed by Swuamy and Arora (1972) is applied.

When considering the results of the proposed estimations, the LM test shows a certain degree of heteroskedasticity. Although the cause of this problem is unknown, its solution requires that the heterogeneity of the data be avoided. In this sense, our sample is made-up of 1,596 families living in the city of Zaragoza, which is divided into three different areas for which the water meter reading is carried out in a different month. If we divide the total sample into these three areas and carry out a different estimation for each of them, we find that the value of the LM statistic to test for heteroskedasticity falls considerably in many cases.

6. Results of the estimation

The results obtained when estimating demand model (2) are set out in Tables 1, 2 and 3. More specifically, in Tables 1 and 2 we have the estimation of the parameter δ, both for the city in its totality and for the three water meter reading areas into which it is divided, obtained by way of the two earlier described techniques, together with the corresponding price elasticities (η) -maximum, minimum and average-.

TABLE 1
TWO-STEPS ESTIMATION (OLS-GLS)

	$\bar{\bar{\delta}}$	$\eta_{max.}$	$\eta_{min.}$	$\bar{\eta}$	Var(η)
Total estimation (T=15960)	-0.0015951 (-1190.74022)	-0.0038549	-0.67396	-0.055276	0.0012815
Area 1 estimation (T=5740)	-0.0010160 (-106.15645)	-0.0024553	-0.42927	-0.035565	0.00059662
Area 2 estimation (T=6150)	-0.0032408 (-240.28658)	-0.017265	-0.61479	-0.10621	0.0040415
Area 3 estimation (T=4070)	-0.0010111 (-168.76767)	-0.012753	-0.27088	-0.037408	0.00058047

TABLE 2
TWO-STEPS GLS ESTIMATION

	$\bar{\bar{\delta}}$	$\eta_{max.}$	$\eta_{min.}$	$\bar{\eta}$	Var(η)
Total estimation (T=15960)	-0.0015509 (-3413.4947)	-0.0037480	-0.65528	-0.053744	0.0012115
Area 1 estimation (T=5740)	-0.0011164 (-218.30219)	-0.0026979	-0.47168	-0.039079	0.00072033
Area 2 estimation (T=6150)	-0.0020435 (-78.91894)	-0.010886	-0.38765	-0.066971	0.0016068
Area 3 estimation (T=4070)	-0.0016060 (-137.92072)	-0.020256	-0.43025	-0.059418	0.0014645

From these Tables we can note that the parameter has a negative sign, in consonance with normal demands where quantity and price have an inverse relationship. Thus, in the face of an increase in their water bill, the residential users in the city of Zaragoza will respond by reducing their consumption. However, as is made clear by the estimated price elasticities, this response will be in a lower percentage, given that in all the cases presented these elasticities are lower than 1 in absolute value -inelastic demand-.

Table 3 presents the estimations of the parameters corresponding to the other variables included in the original model (1): income ($\hat{b}_1$), the number of residents in the household ($\hat{b}_2$), the availability of a common supply of hot running water in the building in which the flat is located ($\hat{b}_3$), as well as that of the independent term ($\hat{b}_0$).

TABLE 3
ESTIMATION OF THE PARAMETERS OF THE INITIAL MODEL*

	Estimation procedure for δ	$\hat{b}_0$	$\hat{b}_1$	$\hat{b}_2$	$\hat{b}_3$
Total estimation (T=15960)	MCG-MCG	-1.98903 (-60.3148)	$0.215698\ 10^{-7}$ (5.74129)	0.263136 (29.903)	-0.169376 (-7.31252)
	MCO-MCG	-1.98878 (-59.5197)	$0.21639\ 10^{-7}$ (5.75258)	0.263465 (29.9032)	-0.169588 (-7.31295)
Area 1 estimation (T=5740)	MCG-MCG	-2.03225 (-39.7585)	$0.151789\ 10^{-7}$ (2.69433)	0.27534 (19.6982)	-0.1612 (-3.04974)
	MCO-MCG	-2.03274 (-39.8858)	$0.150635\ 10^{-7}$ (2.68179)	0.274487 (19.6953)	-0.115695 (-3.04714)
Area 2 estimation (T=6150)	MCG-MCG	-1.98762 (-32.3909)	$0.368007\ 10^{-7}$ (4.46887)	0.250998 (17.0261)	-0.24056 (-6.40106)
	MCO-MCG	-1.97834 (-31.2786)	$0.390208\ 10^{-7}$ (4.59732)	0.258409 (17.006)	-0.247473 (-6.39453)
Area 3 estimation (T=4070)	MCG-MCG	-1.95823 (-28.812)	$0.185779\ 10^{-7}$ (2.96746)	0.260318 (14.4943)	-0.147801 (-2.96746)
	MCO-MCG	-1.96051 (-29.838)	$0.174057\ 10^{-7}$ (2.87441)	0.255717 (14.7289)	-0.142932 (-3.18692)

* Save for the price parameter δ.

TABLE 4
INCOME-ELASTICITY

	Estimation procedure for δ	$h_{y_{max.}}$	$h_{y_{min.}}$	$\bar{h}_y$	$Var(h_y)$
Total estimation (T=15960)	MCG-MCG	1.00267	0.019172	0.10652	0.0043074
	MCO-MCG	1.00589	0.019233	0.10686	0.0043351
Area 1 estimation (T=5740)	MCG-MCG	0.70559	0.020762	0.071374	0.0024432
	MCO-MCG	0.70023	0.020604	0.070831	0.0024062
Area 2 estimation (T=6150)	MCG-MCG	0.54605	0.046977	0.18455	0.0070958
	MCO-MCG	0.579	0.049811	0.19569	0.0079778
Area 3 estimation (T=4070)	MCG-MCG	0.55606	0.016032	0.092987	0.0043277
	MCO-MCG	0.52274	0.015071	0.087415	0.0038245

TABLE 5
ELASTICITY WITH RESPECT TO THE NUMBER OF RESIDENTS

	Estimation procedure for δ	$h_{n_{max.}}$	$h_{n_{min}}$	$\bar{h}_n$	$Var(h_n)$
Total estimation (T=15960)	MCG-MCG	2.10509	0.26314	0.81165	0.11134
	MCO-MCG	2.10772	0.26346	0.81266	0.11162
Area 1 estimation (T=5740)	MCG-MCG	2.20272	0.27534	0.84367	0.12669
	MCO-MCG	2.1959	0.27449	0.84106	0.12591
Area 2 estimation (T=6150)	MCG-MCG	1.75699	0.251	0.73671	0.098533
	MCO-MCG	1.80886	0.25841	0.75846	0.10444
Area 3 estimation (T=4070)	MCG-MCG	1.82198	0.26028	0.8691	0.10076
	MCO-MCG	1.78983	0.25569	0.85377	0.09784

In the light of the results obtained, it should be noted that the income, approximated by way of the fiscal value, has a direct relationship with the consumption of water, as demonstrated by the positive sign of β_1, although the corresponding elasticity which is obtained indicates that this is very reduced. This result is in line with those presented in other studies, such as, for example, those of Dandy, Nguyen and Davies (1997), Hansen (1996) or Nieswiadomy and Molina (1989).

Similarly, the number of individuals in each household generates a positive effect on family water consumption (β_2). Again, this is clearly in line both with the results estimated in other empirical works, for example, those of Howe and Linaweaver (1967), Hanke and De Maré (1984) or Nieswiadomy (1992), and with that expected from a simple exercise in logic.

For its part, the estimation of the parameter corresponding to a dummy variable that indicates the availability, or otherwise, of a common supply of hot water in the building (β_3), presents a negative sign in all cases. This corresponds with the initial forecast that the existence of a hot water supply which is alternative to that provided by the public service, and where the latter is reflected in the individual water meter of each user, leads to a fall in the consumption registered on these meters. This is the case because part of the water used, especially in the winter months, is obtained from the common supply system installed in the building.

7. Final considerations

In this paper, we have used a dynamic panel data approach to estimate the water demand function in the city of Zaragoza. As a result we have noted that although the tariff structure established by the City Council is such that consumers to reduce their consumption in the face of an increase in prices, as demonstrated by the sign of the parameter δ presented in Tables 1 and 2, such a response is very limited, given that the elasticity is situated in absolute values below 1 and close to 0.

Thus the capacity of demand policies based exclusively on prices to encourage an efficient use of water is very limited. This situation can be explained by a combination of three elements. First, because water is a primary commodity, as shown by the estimated value of β_1, offered under a regime of monopoly, which prevents its users from changing supplier. Secondly, because individuals do not have well substitutes available for many of the residential uses of water: personal hygiene, cleaning, etc. Thirdly, by virtue of the reduced percentage that the water bill represent in relation to family disposable income. In this context and save for when the price increases by a considerable amount, individuals will have no incentives to reduce their consumption since users will continue to spend a small fraction of their incomes on water. However, a dramatic increase in the price, which allows the sensitivity of demand to improve in the face of changes in that price, will cause problems from the point of view of equity. In these circumstances, many low-income individuals would see their access to such an indispensable good as water made more difficult, thereby suffering a fall in their quality of life, in the form of poorer hygiene conditions, bad diet, etc.

For their part, the values obtained for the income elasticity and the elasticity with respect to the number of residents allows us to draw certain conclusions on the limitations suffered by tariff-based measures as an instrument of water management. First, we can note that although the water used by households initially has the character of a primary good, it progressively becomes converted into a luxury good as the income levels of these households increase, with the water consumed being allocated to a series of non-basic uses: watering the garden, swimming pools, etc. In this way, a process of steadily increasing income, such as that produced in the last few years, would mean that the demand for water could rise significantly in the medium term. This would be the consequence of the change in the consumption patterns of families that goes hand in hand with the increasing trajectory of disposable income. Such a phenomenon would counteract, or even annul, a significant part of the income effect associated with increases to the prices of the resource. Secondly, although the elasticity with respect to the number of residents indicates that the amount of water consumed increases with the number of members of the household, this increase is less than proportional, in that there is a set of indivisible basic forms of consumption allocated to common household uses: domestic cleaning, etc. This circumstance implies that if the number of households increases, although the total population does not, the consumption of water would also increase independent of the price established.

Thus, we can conclude by indicating that the use of tariff-based measures could help to rationalise the consumption of water on the part of urban users. However, if what is really desired is to achieve the “optimal use pattern” referred to by Winpenny (1994), then these must be complemented by other policy measures. Such measures could take the form of educational and informational campaigns aimed at making the population more aware of the real scarcity of the resource. Similarly, incentives could be offered for the use of water-saving technologies and consideration given to measures directed towards improving the efficiency of the distribution system in order to avoid leaks and illegal connections.

8. Notes

(1) As indicated by Chicoine and Ramamurthy (1986), Foster and Beattie (1981) and Opaluch (1982 and 1984) the price variable that is selected must reflect the view that the consumers have of it. Specifically, the perception that individuals have of the price variable depends, according to Shin (1985), on the degree of knowledge that these posses of the tariff structure. It is habitually the case, that individuals do not have the technical or economic capacity to handle perfect information, in such a way that they will opt for other alternatives that are more accessible to them. Therefore, the cost associated to the obtaining of information will be that which ultimately induces consumers to act in function of one or another characterisation of the price.

(2) In this sense, see Blundell, Bond, Devereux and Schiantarelli (1992).

(3) See Arellano (1989), Arellano and Bond (1991) and Baltagi (1999).

(4) Given that v_{it} ~IID$(0, s_v^2)$, we obtain that $E[\Delta v_i \Delta v_i'] = s_v^2 G$ with G being a squared matrix TxT of the form

$$G = \begin{pmatrix} 2 & -1 & 0 & 0 & \dots & 0 \\ -1 & 2 & -1 & 0 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & \dots & -1 & 2 \end{pmatrix}$$

and $\Delta v_i' = (v_{i4} - v_{i3} \quad v_{i5} - v_{i4} \quad \dots \quad v_{iT} - v_{iT-1})$.

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